3 **Proceedings**

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CALIFORNIA RICE RESEARCH SYMPOSIUM
WESTERN REGIONAL RESEARCH LABORATORY
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William J. Duffy, Jr. - Presiding

9:00 a.m.	Welcome	Dr. M. J. Copley
9:15	General Features of the Rice Research Program at the Western Regional Research Laboratory	James W. Pence
9:30	Effects of Certain Preprocessing and Cultural Variables upon Milling and other Processing Qualities of Rice	Ernest B. Kester
10:00	Canned Rice–A New Convenience Food	R. E. Ferrel
10:30	Warming Basins and Water Temperature .	Franklin C. Raney
11:00	Weed Control Research at the Rice Experiment Station	Kenneth L. Viste
11:30	Biology and Control of Insects and Other Invertebrate Pests Affecting Rice in California	W. H. Lange
12:00 - 1:30	Lunch	
1:30	Improved Procedures in Artificial Drying of Rice	Ted Wasserman
2:00	Studies of Unheated Air Drying of Rice .	S. Milton Henderson
2:30	Nutritional and Physiological Studies on Rice (not included herein)	Duane S. Mikkelsen
3:00	Iron Deficiency of Rice	W. E. Martin
3:30	Improving Rice Through Breeding	Milton D. Miller
4:00	Green Manure and Crop Residue Management in Rice Production	Dwight C. Finfrock

GENERAL FEATURES OF THE RICE RESEARCH PROGRAM AT THE WESTERN REGIONAL RESEARCH LABORATORY

James W. Pence

Research on rice at the Western Regional Research Laboratory is balanced equally between practical (or applied) and fundamental efforts. At present the program comprises five active projects. One, a project of the Engineering and Development Laboratory in cooperation with the Southern Regional Research Laboratory, is on the application to medium- and long-grain varieties grown under southern conditions, of principles and improved procedures developed for commercial drying of short-grain rices.

Before current projects in the Cereal Investigations of the Field Crops Laboratory are described, brief attention should be given to a project completed about two months ago. This project was concerned with measuring amino acids and certain other organic acids associated with respiratory processes in stored grain. Free amino acids were found not to change in quantity during storage under good or poor conditions or to be associated with the development of browning in paddy during storage. The plant acids were found to occur in similar relative amounts in representative types of domestic rice. Relative proportions of the same acids varied among different milling fractions. The acids proved to be sensitive components of rice and showed variation in total and/or proportional amounts under such varied conditions as differences in harvest maturity, parboiling treatment, occurrence of heat damage, and storage under adverse conditions. Quantities increased during storage under either warm or moist conditions and paralleled other quality changes in stored rice. Subsequent research will be directed toward developing simplified methods of analysis useful for quick evaluation of the quality factors of rice that may be directly related to the changes in plant acids.

One of our current projects is concerned with stabilization of brown, undermilled, and parboiled rice and of our quick-cooking rice cereals against rancidification. This project will entail treatment of the stored material with selected antioxidants, followed by storage at several temperature and moisture conditions. Important work has already been done in this area, but published information is not yet extensive enough to provide all the information necessary to utilize these products to the fullest extent.

Another of our active projects concerns processing of short-grain rices. The project is rather broadly drawn so that exploratory work on the effects of a number of processing variables can be examined in a preliminary way to determine those worthy of more detailed investigation. The treatments to be examined will include heat, acidity, hydration under varying conditions, treatment with enzymes, and treatment with oxidizing or reducing gases, surface-active agents, etc., and their effects on the protein and starches of rice and on the over-all behavior of the rice when subsequently processed into prepared food items. It is under this line project that work on canned rice is currently being conducted. Mr. Ferrel will describe this work in greater detail.

We hope under this project to complete development of other food items, such as our quick-cooking breakfast cereals from both white and brown rice. The products are relatively advanced at present, but require a certain amount of additional work to make them as appetizing, as stable, and as finished as we think they should be before active promotion.

Another project is cooperative with the Biggs Station. Observations made during one of the fall drying campaigns, in which WRRL personnel applied laboratory-developed drying principles to commercial drying of rice, indicated that there was a progressive loss in head yields when rice was allowed to dry below 23 to 25% moisture before being harvested. It

was concluded that a comprehensive study should be made to establish accurate relationships between the moisture of rice at harvest and its behavior in drying and subsequent milling. The relationships of harvest moisture and other cultural conditions to nutritive and cooking qualities and to chemical composition of rice are equally important and will also be studied. Dr. Kester's paper will describe the present status of this work.

The final project I want to describe concerns a survey of the characteristics of rices available in principal world markets. Its aim is to obtain guidance for more informed and effective export marketing of U. S. rices. Since distinct preferences exist throughout the world for particular kinds or types or grades of rice, it stands to reason that directing our exported rice to its most favorable markets will be of great benefit in increasing export tonnages and stabilizing offshore markets.

Accordingly, the Foreign Agricultural Service has begun collection of several hundreds of individual samples of rice from all over the world. These are graded and otherwise evaluated according to U. S. grades and market standards. At various laboratories they are further subjected to cooking tests, proximate analyses, analysis for surface lipids, amylose-amylopectin ratio, grain dimensions, color evaluations, response to dilute alkali, water uptake at 77° and 82° C., amylograph tests, and histological characteristics. At our laboratory, nearly 200 samples have been analyzed at least partially for about a dozen of these factors. Other cooperating laboratories are the Southern Regional Research Laboratory, the Institute of Home Economics, and the Beaumont Station of the Crops Research Division of ARS.

Results are accumulating steadily, but it is too soon for systematic collation and evaluation.

Speaking generally, again, perhaps our greatest need in studies on

the utilization of rice is more fundamental information on rice constituents and the way they are related to quality characteristics. We need a great deal more information on the more obscure chemistry of rice and its constituents. By this I mean we should know something of the degree of branching of rice amylopectin, the average and range of molecular sizes of the amylose and amylopectin components, the alpha- and beta-amylase contents and their effect on viscosity and cooking characteristics, and so forth. Almost nothing seems to have been done to determine what effects the proteins of rice may have on its cooking or other quality characteristics. This, I am sure, has not been intentional. Rather, I think that the relatively low amounts of protein in rice have made people feel that starch characteristics could not help but be the most important. Maybe they are, but we do not know. The groups previously working exclusively on rice and on wheat at our laboratory have been combined into a larger group concerned with both cereals at once, making available a sizable backlog of experience with cereal proteins to apply on rice proteins. As soon as we can manage it, we intend to study the rice proteins in some detail.

I do not intend to discount in any way the importance and need for applied work on product development, and so on, but the best possible foundation for applied work is a solid base of fundamental knowledge about the materials being used. We will continue to keep the applied and fundamental aspects of our rice research program in good balance.

EFFECTS OF CERTAIN PREPROCESSING AND CULTURAL VARIABLES UPON MILLING AND OTHER PROCESSING QUALITIES OF RICE

Ernest B. Kester

Production and utilization studies by government agencies are often considered to be distinct areas requiring quite different scientific and technical disciplines. This is true to a considerable degree. Nevertheless

there is a region of overlapping that requires close cooperation between workers in both. The project I am about to discuss, in which our cereals group here and the Biggs group have cooperated, illustrates this point extremely well, and I believe production and utilization people will continue to combine efforts to their mutual advantage.

We have had occasion to cooperate with the Biggs Station in a previous major investigation--our storage project--and I must say the teamwork between our two groups was excellent then as it is now, and resulted in much useful information on rice storage.

During our experimental work at California rice drying plants, it was observed during harvest that head rice yields decreased with a decrease in harvest moisture. In the tests at Sutter Basin Cooperative, the loss amounted to about 1.7% head yield for Caloro in the range of 25.2 to 14.7% field moisture, and about 1.5% for Colusa for every 1% reduction in field moisture on a straight-line basis. These observations suggested the need for a closely controlled study to determine more precisely the relationships of these variables, and after consultations with Dwight Finfrock, our group agreed to set up a two-year cooperative project with the Biggs Station to evaluate the effects of maturity on the milling yields of rice, and incidentally to learn as much as possible about other changes in the rice grain during maturation. Tests of seedling vigor, germination, and acreage yields on these samples would be run at the station.

This program was activated during the 1957 harvest, and was continued in 1958. The 1957 program involved a Caloro and a Calrose series in which samples of each were harvested from Station plots starting at 36.5 and 33.3% moisture content, respectively, and continuing every two or three days until the field moisture of the samples was about 14 to 15%. There were 14 samples in each series. The rice was harvested in late afternoon and shipped to the Laboratory by bus, arriving the following morning.

From the ensuing tests on these rices, we concluded we hadn't started early enough in the collection of samples. In 1958 we corrected this error, and our collaborators up at Biggs began collecting samples when the respective field moistures for Caloro and Calrose were 58.0 and 53.9%. Samples were obtained daily to avoid wide gaps in the moisture content of successive samples. In all, we obtained 41 samples of Caloro and 45 samples of Calrose during the fall of 1958. We also had a Colusa series from the Station, but this early-maturing variety got a little ahead of us, with the initial sample at 34.6% moisture instead of in the 50's, as with the other two varieties.

On receipt, the samples were immediately placed in our sample dryer and dried with 80° F. air to about 13.5% moisture. These mild drying conditions were selected because we had found that they caused little or no checking of kernels. About a pound of each dried sample was then returned to Dwight Finfrock for his own work.

Portions of the dried samples were given the standard milling test. From the milling data, total and head yields were computed, and certain additional tests, both chemical and physical, were made to learn what happens to or within the rice kernel as it matures.

Milling yields.--In 1957, total and head yields reached a maximum in the harvest moisture range of 28 to 31% for Caloro and 25-28% for Calrose. From there on, total yields remained fairly constant though head yields dropped off at the rate of about 0.5% for every 1% loss of moisture in Caloro, and 0.7% for every 1% moisture drop in Calrose. These losses were somewhat lower than had been observed at the plant, but nevertheless confirmed previous findings qualitatively.

In 1958 the collection of the Caloro and Calrose series started early enough for our purposes. Indeed, the first few samples in the higher moisture ranges were so brittle and chalky after being dried that we were unable to get milling data on them. But, starting with the 7th or 8th samples, we

obtained milling yields of about 49% total and about 23-27% head rice. These values increased progressively as field moisture diminished, just as in the 1957 samples, and showed plateaus for total rice and maximum head yields at about the same points. Calrose showed a somewhat wider range of moisture content for maximum head rice (22 to 27%) than in 1957, and Colusa was about the same as Calrose.

During the decline in head yield from the maxima, the losses were about 1.4 for Caloro, 0.9% for Calrose, and 1.0% for Colusa for every 1% reduction in field moisture. These values are somewhat higher than those computed from our 1957 data, but not far different from what was observed at the Sutter Basin plant.

Kernel weight.--Data obtained on the 1957 samples indicate that kernel weight increases with initial reduction of moisture, with the curve showing a change of slope at about the same point as the milling yields. The kernel weight data were interpreted on the basis of brown rather than on rough rice, which showed rather wide fluctuations even after six replications were averaged. Our kernel weight determinations on the 1958 samples are now being run, and no data are yet available.

Chemical analysis.--Total nitrogen, determined on all the 1957 samples, remained essentially unchanged throughout the two series. The amino nitrogen content of water extracts of the Caloro series underwent a definite decrease, to about one-fourth its initial value, indicating that peptides and proteins were continuing to be formed.

In the 1958 series we have analyses for total nitrogen, crude fat, fiber, and ash for the initial and terminal samples and for samples at the point where the rices reached maximum milling yields. As with the 1957 samples, the nitrogen values were about at the same level for these points in all three of the rices. On the other hand, crude fat, ash, and fiber declined consistently with maturation. Many more of these samples will

need to be analyzed, of course, to determine the shape of the curves and to see if correlation occurs between milling yields and chemical composition.

Preliminary results on short-chain nonamino organic acids on the 1957 Calrose samples showed marked differences between the first and last samples of the series; the immature sample showed nearly twice as much organic acids as the first sample.

Other chemical tests in progress, particularly on the 1958 series, are analyses for total starch and amylose. Here again we started with three samples from each series--the initial and terminal samples and one intermediate sample representing the rice when it reached maximum milling yields. Within any one of these groups of samples, the differences in starch percentages are not wide. Total starch showed an initial increase of about 1.5% for Caloro and Calrose, but none for Colusa. Amylose in all cases went up 1.1 to 1.7% from the initial to the intermediate samples. These increases may or may not be significant. We are now testing the precision of our analytical methods for starch and amylose, but until we obtain this information we will not be able to draw conclusions regarding such small differences as indicated by the analyses.

Tests related to processing quality.--With reference to gradations in processing qualities of rice as it matures, several tests are available to the investigator, such as swelling number, water uptake at fixed temperatures, and behavior of pastes in viscosity tests. At the Western Laboratory we have worked with the Brabender Amylograph, a device for measuring viscosity in arbitrary units, and have been able to replicate results fairly consistently. This instrument is so constructed that it measures and records viscosity of the pastes while undergoing a temperature rise of exactly 1.5° C. per minute. We run this test with pastes of about 10% concentration. At 30°, the temperature at which the test starts, the paste

shows very little measurable viscosity with this instrument, and continues in this condition until the temperature climbs to about 65 to 70°, when the curve begins to turn upward, indicating a viscosity rise. The paste continues to thicken with increase of temperature, finally reaches a peak, and starts to decline. Most of our rice samples peak around 92-93°. At 95°, the viscosity has fallen considerably, and we hold the paste at this temperature for 20 minutes, and then cool it, at the same rate as it was allowed to rise (1.5° per minute), until it has reached 50°, when we record the viscosity for the last time.

The most significant point recorded is peak viscosity, where the widest differences were found in curves of a series. After that point, temperature and shearing action of the equipment break down the body of the paste so that its viscosity diminishes rapidly. Indeed, the fall of viscosity is so rapid that it is difficult to determine at our top temperature of 95 with any degree of accuracy. An error in the thermometer reading of a small fraction of a degree may make a difference of 50 to 100 units in viscosity reading.

When we ran the Viscograph tests on the initial and terminal samples of the Caloro and Calrose rices in the 1957 series, we found, to our surprise, very little difference in viscosity characteristics in either case, probably because we started taking samples too late. Somewhat wider differences in viscosity were found in the 1958 series, when the first samples that could be milled were compared with the terminal samples, the viscosity showing an increase with maturation.

So far in our work, the principal change in rice as it matures seems to be an alteration of its physical condition--in other words, the change from chalky to harder, more compact grains, and an increase in weight. These changes do not seem to be reflected in alteration of chemical composition, as far as our tests have gone, and only to a limited degree by

certain aspects of physical behavior. We have considered supplementing tests already in progress with some structure studies using optical and crystallographic techniques, which Dr. Jones of this Laboratory has agreed to do.

Fertilizer effects.--In addition to the three maturity series, Finfrock also sent us nine samples of fully mature Caloro or Calrose rices from each of four farms, on which each of the nine samples was grown on soil with different fertilizer treatments; all possible combinations of 0, 30, and 60 pounds of phosphorus and 0, 40, and 80 pounds of nitrogen per acre were represented. There were also six samples from one farm in which the P-30 series was absent, and replications of Station plots where only nitrogen was used at 0, 30, and 60 pounds per acre. All of these were dried by our standard method and given the standard milling test. The data were then organized to see if there were consistent patterns in milling yields that could be related to the fertilizer treatment. No specific effects of either increasing nitrogen or increasing phosphorus were evident, and it is doubtful that the correlation would be high. We thought that the replicated series from the Station plots with only nitrogen applied to the soil might show a trend in milling yields, but the average of the replicates for 0, 30, and 60 pounds of nitrogen agreed with each other within 1.2% for total and 1.0% head, which is about as good as one can do with the milling test on split samples. No further data on these samples of known fertilizer history, such as chemical analysis, amylograph curves, and the like, are yet available, but these will be obtained in due course.

What I have presented today is a progress report. Much remains to be done--the additional viscosity work, more chemical analyses and physical tests such as water uptake--before we have a reasonably complete picture of maturation effects.

CANNED RICE--A NEW CONVENIENCE FOOD

R. E. Ferrel

One aspect of our rice research program concerns the development of new and convenient food uses for rice. Several such new products have been or are in the process of being developed here. Perhaps the most successful of these, or at least the one arousing the most interest at present, is canned California pearl rice.

This is a fully cooked white rice requiring only 2-3 minutes to complete hydration and heat for serving. It is in every way equal to freshly prepared rice and superior to it in separation of grains. The development of this product is what I'm going to discuss today.

From time to time, canned rice has been available on some grocery shelves as a specialty item, usually associated with oriental foods. These products, however, have usually been either an unpalatable mass of pasty kernels or have been prepared from parboiled rice and lacked the characteristic white color and delicate rice flavor most consumers expect.

A few years ago this laboratory undertook to develop a satisfactory canned cooked white rice, and came up with a product that was a great improvement over previous canned rices.

The process is simple, requiring only that the rice be soaked to equilibrium moisture (about 30%), cooked at a temperature above the gelatinization point to appropriate moisture content, packed into cans, sealed under high vacuum, and retorted to ensure sterility. The novel and critical points of the process are control of moisture and pH, use of proper cans, and vacuum sealing.

It was found that moisture content at canning should be held between 45 and 60%. Although rice is normally consumed at about 65-70% moisture, attempts to can at this moisture level resulted in pasty kernels. Below 60% moisture the kernels remained intact and separate. Any moisture

content below 60% could be used, but the practical lower limit was at about 45%. Below that, kitchen preparation time became too long to make it a true convenience item.

Since alkaline conditions promote discoloration of rice, it was necessary to acidify the water used in hydrating the rice to pH 5.0-5.5 with acetic acid, to ensure the brilliant white color desired.

Rice, in common with corn and other cereal grains, contains sulfur compounds that break down during processing and react with iron and tin to give black sulfides on the can and rice adjacent to the can. Moreover, the odor of free hydrogen sulfide can be detected when such cans are opened. "C" or corn enamel can linings contain zinc oxide, and the liberated hydrogen sulfide reacts with this to form odorless white zinc sulfides, thus eliminating these two problems.

If the processed rice is sealed in the cans at atmospheric pressure, a marked grey to brown discoloration occurs during storage. Sealing under 26" or higher vacuum prevents this discoloration.

The retorting step not only serves to sterilize the product but completes the gelatinization or cooking. This makes it necessary only to heat the product with a small amount of water to complete hydration and prepare it for serving.

The results of this work were published in Food Technology, and a patent on the process was obtained, but it aroused little interest among canners. To our knowledge, only one small cannery in Louisiana is now marketing rice canned by this process. As you might suppose, they are using long-grain rice.

The Quartermaster Corps has also shown interest in the product, and a Military Specification covering it is drawn to include both long- and short-grain rices.

In 1956 the Agricultural Marketing Service became interested in

promoting canned pearl rice, and suggested a market test. Following a series of conferences a memorandum of understanding was signed in December 1956 by the California Rice Industry as represented by the California Rice Export Corp., the Agricultural Marketing Service, and this Laboratory whereby such a test could be activated.

Briefly, the Rice Industry was responsible for supplying the rice, cans, and labels and getting the product packed and supplying funds for the advertising and promotional campaign. The A.M.S. was to arrange for and conduct the market test and consumer survey and to analyze and report the results. This Laboratory was responsible for the technical supervision of processing, the conduct of control and quality tests, and the checking of technical correctness of recipes, label directions, and promotional claims.

Fresno was chosen as the test city. The test began on May 13, 1957, and continued into September of the same year.

California Packing Corp. was selected by the rice industry as the company to pack the rice for the test. After several consultations with their representatives concerning equipment and processing procedures, I proceeded to their plant in Spanish Fork, Utah, where the work was to be done. We expected to complete the job in a week to ten days.

Anyone less naive than I would probably shudder at the thought of adapting a laboratory process to commercial practice with a six-week deadline. In any case, the first few days quickly disillusioned me as to the ease with which the job was going to be done. I don't believe a single piece of equipment worked as we had so carefully planned. Moisture and pH control were difficult, the pump plugged up and crushed the rice, the hopper of the can filler plugged continually, we couldn't achieve a high enough vacuum, and cans paneled during retorting. In short, about everything that could possibly go wrong did just that. Finally, however, by

modifying, adapting, moving equipment around, bringing in equipment from other plants, and fabricating some, we finally succeeded in canning about 27,000 cans with over two weeks to spare--or so we thought.

After returning to the lab with samples from each of the thirty-two lots processed, we started checking the product. To our horror we found that about 20% of the cans had lost their vacuum. After many hurried consultations with experts from California Packing Corp. and Continental Can Co. it was determined that the difficulty was in faulty can construction but that the faulty cans could be segregated by flip testing and the remainder could be safely used.

As you probably know, the ends of a can are curved inward slightly. If a pressure differential is applied across this end it will snap out to the opposite position. In flip testing, a vacuum is applied to one end of the can. If there is still a vacuum inside the can nothing happens, but if the vacuum has been lost, the can end will change position with a sharp snapping sound which can be easily heard.

So, a flying trip to Spanish Fork was made and the 27,000 cans were flip-tested. About 5,000 were rejected. The remainder were then labeled and shipped to Fresno--three days before the beginning of the market test.

Here I would like to say that the job could never have been completed in time without the very fine cooperation of the personnel at the Spanish Fork plant, the local representatives of California Packing Corp., the rice industry, and in fact everyone concerned.

The market test was conducted under the supervision of Mr. Robert Enochian, of the AMS, now assigned to this laboratory. A comprehensive report of their findings has been published. I shall not attempt to go into the details of the market test, but merely quote some of the pertinent conclusions drawn from the study.

"Insta Rice, the name given the product, attained a favorable sales position relative to quick-cooking dry rices, canned Spanish rice, and

canned long grain white rice during the market test period.

"Although stores serving low income groups sold more rice of all kinds, sales of Insta Rice were highest in stores serving medium and high income groups. This suggested that the product was perhaps tapping a new rice consumer market among people who normally used little or no rice.

"Ten weeks after the beginning of the market test a hosehold survey was conducted among a representative sample of homemakers in the Fresno area.

"Survey results showed that about 1/4 of the homemakers were aware that Insta Rice was being sold in local stores and that 1/2 of these had bought the product. One-third of these users had purchased the product more than one time and 8 out of 10 expected to continue using it from time to time.

"A majority of the homemakers who had tried the product expressed favorable opinions of its taste and cooking properties.

"Most store managers that had stocked the new product indicated they would continue to carry it on a regular commercial basis if the product were promoted as often as other established rice products.

"During the market test in Fresno, the average weekly sales per $20,000 of weekly store volume was 4.8 units per week for the 11 dry rice items stocked, and 4.5 units per week for Insta Rice. These figures are for the last 13 weeks of the test period, after the effects of primary promotion had worn off to a large extent.

"Thus it appears that if Insta Rice were made available on a regular commercial basis, and if it were promoted as often as other established rice products it could be expected to achieve a sales rate equal to or greater than the average sales rate for all rice products sold in Fresno."

This survey then presented a very encouraging picture. And since its publication much interest has been expressed in the product by several large firms.

The test did reveal, however, one defect in the product. A significant number of users reported difficulty in getting the product out of the can and separating it into individual kernels. This defect we have since attempted to overcome.

We felt that what was needed was to alter the surface of the rice kernels in such a way that they would not stick to one another. Several ways of doing this appeared possible. The simplest and most direct approach appeared to be to coat the grains with some edible material that would prevent this cohesion of kernels.

A few experiments indicated two methods by which this could be done: First, by using dilute oil emulsion to form a protective film, and second, by the use of certain emulsifiers alone.

In order to have some objective measure of the degree of improvement, we use a standardized shaking test. The contents of a can of rice, aged seven days, are placed in a special shaker screen, having holes large enough to permit passage of single kernels of cooked rice but hold back small clumps. This is shaken two minutes in a reciprocating shaker, and the reduction in cohesion is then expressed as the percent, by weight, of single kernels passing the screen. The higher this percentage the greater the improvement achieved.

The net weight of rice packed in the can must be controlled within close limits since an approximate 5% increase in weight of rice per can reduces the measured percentage to about 1/2 the original value.

Moisture also has an effect, though small--about a 1% reduction in per cent passing the screen for each 1% increase in moisture, in the range of 50-55% moisture.

Applying the treatments at all three of the precanning steps, soaking, cooking, and rinsing, gives maximum results; however, applying the treatment at the final rinse just prior to filling into the cans gives an effect

nearly as great. Since this would be simplest, and most economical in both material and equipment in a commercial process, we are using this method of treatment in our studies, which are continuing.

Length of treatment does not appear to be a critical factor: a one-minute rinse gave about as good a reduction in cohesiveness as did a 5-minute rinse. It thus appears probable that the emulsions could be applied as a spray to the rice as it moves along a conveyor to the can-filling operation.

Tests on the effects of oil or emulsifier concentration are under way, but results are not yet available. One preliminary experiment indicated that about 3% oil in the emulsion is the minimum that will give a significant reduction in cohesiveness. To be well above this minimum we have used 5% oil emulsions in all our work to date.

Using this concentration the finished product contains only about 0.5% oil. Taste-panel comparison of such treated samples with untreated controls appears to be on the borderline of significance. That is, about 70% of the judgments correctly identified the treated sample. Some of the panel members have had a great deal of experience in detecting oily flavors in foods. On this basis and the bare significance of evaluation by direct comparison with an untreated control it is probable that the ordinary consumer would be unable to detect any change in flavor. Three months' accelerated storage at 100° F. had no detectable effect on the flavor of oil-emulsion-treated samples.

We have not achieved the goal of a product that will pour from the can like dry rice, but we have achieved a marked reduction in cohesiveness, with either oil emulsions or emulsifiers alone. The oil emulsion gave about 90% separation of grain in our test, emulsifiers gave about 70% separation, and untreated controls had about 25% separation.

What the effects of these treatments are we can only speculate on at present. We know that regular canned rice, in the first 2-4 weeks after

processing, undergoes certain changes that make it superior in grain separation to freshly prepared rice. Because these changes show similarities to the staling or firming of bread, we believe that it is a retrogradation or crystallization of the starch.

The cohesiveness of the untreated rice, we think, may be due to cross-crystallization of the starch between highly hydrated kernels in intimate contact with one another. These treatments, we believe, are effective because the hydrophilic end of the emulsifier molecule penetrates the surface layer of hydrated starch granules and the protruding lypophilic end either holds a layer of oil on the surface of the kernel or, being in itself of a oily nature, exerts some of this same effect. Thus, reducing the number of contacts between the hydrated surface granules of the different kernels reduces the amount of cross crystallization, and therefore the cohesiveness.

WARMING BASINS AND WATER TEMPERATURE

Franklin C. Raney

Every year, California rice farmers plant some 450 square miles of rice, almost 85% of it in the counties north of Sacramento. During some years, nearly 3% of the average (over 12 square miles) is lost because of cold-water damage in the first few intake checks. Were acreage restrictions removed, our rice acreage would possibly double or triple. Our cold-water losses would, of course, increase too. It is even possible we would be faced with an even greater percentage loss from cold water damage than at present.

We are committing ourselves to a vast program of dam construction to control our rivers, even-out river flows, produce power, and provide reliable irrigation supplies for expected expansion of population and irrigated

agriculture. Because of the short transit time for water between the high-altitude cold-water sources and the narrow, deep storage reservoirs, and through the short narrow, deep conveyance systems between the reservior and the farmers head gate, the water warms up but little before reaching the crop. The farmer commonly accepts water with a temperature of 55-65° F. during the growing season.

When the gates at Shasta dam, on the Sacramento river, were closed in 1946, the river temperature dropped 16° at the dam and 5° at Sacramento. In 1947 the rice farmers, very large water users in the Sacramento river drainage basin, reacted in a very practical way. They installed water warming basins ahead of their field intake weirs. They also called on the University Agricultural Experiment station for help in reducing the damage.

Since this time the departments of Irrigation and Agronomy have been seeking solutions to the cold-water damage problem by research in three related directions:

1. Selection of rice varieties "tolerant" to lower water temperatures.--The main objective here is, at least, to maintain rice grain yields, to reduce the seasonal length required to mature the plant at low water temperatures, and yet to retain or improve other plant characteristics of interest to the grower, miller, and consumer. This is a big order. Breeding and selection take time. This is a long-term but necessary approach, and not unpromising if we are patient and determined. Some day we may have a "certified" cold-water strain from this type of research at the Rice Experiment Station, in the Richvale area of California.

2. Understanding the effect of water temperature on the rice plant at different growth stages.--Whereas selection and breeding may provide us with a basic type of plant that is tolerant to colder water during the over-all growing season, the University departments Irrigation and Agronomy are now acquiring detailed experience that will help us understand the effect

of water temperature on the plant during each stage in its development. We know now, for example, that, for the variety Caloro on Zamora clay in small plots at Davis:

a. the critical seasonal threshold for normal rice plant growth to maturity in 160 days in near 69° F. If the mean water temperature is five degrees lower, the naturity date is delayed 30 days into the fall.

b. rice yields are highest when the mean water temperature is near 80° F.

c. the final yield of rice is independent of water temperature above 65°F. during the planting to tillering stage and after pollination, although maturity is delayed if water temperatures are lower during the season.

d. if mean water temperatures are below 69° at any other growth stage, final rice yields are reduced.

These studies will be continued at the Rice Experiment Station, beginning in 1959, on Stockton clay in small plots. The objectives are:

a. to discover the critical night temperatures for the growth of rice.

b. to identify the minimum temperatures that the rice plant will endure during each growth stage and yet maintain acceptable yields.

c. to compare stagnant and moving water in their effects on rice yields.

d. to compare plant response when water temperatures decrease from the beginning of the season to harvest time with plant response when temperatures rise continually during the season.

When plant behavior patterns of this kind are detailed we will be in a much better position to design efficient water warming ponds, which will probably still be needed to raise the general water temperature level.

3. Design of water warming basins.--Immediate relief from cold-water damage will have to rest on water warming basins. However, the

size of a basin that will largely remove the effects of cold water on rice is dependent on several factors:

1. temperature of the incoming water,
2. time that water remains in the warming basin,
3. weed growth shading water in the basin,
4. energy lost in evaporation from the basin.

The Department of Irrigation has been studying each of these factors, and in time should be able to assign a proper value to each and design a warming basin efficient in raising rice yield while occupying the least real estate. Field studies on the shape of the basin and the pathway of water in it are going on at Davis, but the major effort so far has been to find ways for reducing the loss, through evaporation directly from the warming basin, of 40 per cent or more of the solar energy. A number of floating, evaporation-reducing films have been tried. Some promising ones are being tested that:

1. do not interfere with high transmission,
2. reduce evaporation by 50%,
3. do not accumulate dust,
4. remain spread,
5. are not consumed by the biota,
6. are not prohibitively expensive.

It is immediately evident that these approaches to the reduction or prevention of cold water damage are interrelated. Their separation here is for convenient discussion.

Each contributes something to solution of the over-all problem of rice cold-water damage. Both long-term and short-term aspects are receiving attention. As the California water plan is implemented, water temperature will gain more and more attention, and other crops may also benefit from the current research on rice water temperature relationships.

WEED CONTROL RESEARCH AT THE RICE EXPERIMENT STATION

Kenneth L. Viste

Weed control investigations in rice have involved two aspects of the rice weed problem: 1) injury to rice caused by the phenoxy herbicides (2,4-D and MCPA), and 2) chemical methods of control of watergrass (Echinochloa crusgalli).

The two herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and 2-methyl-4-chlorophenoxyacetic acid (MCPA) have been compared in treatments at different stages of growth. Table 1 shows the results of three years of study. In two of the three years 2,4-D treatment at early tillering reduced yields very severely. In the third year, 1958, 2,4-D caused no injury to rice at any stage of growth. No MCPA treatment reduced yield. The seasonal differences in injury caused by 2,4-D are probably related to temperatures at treatment time. June temperatures were relatively low in 1958. The results suggest that injury by herbicides can be appreciably avoided by using 2,4-D at only the later tillering stages or by using MCPA. The latter herbicide can be used over a wider range of time and is therefore the preferred herbicide, since it provides control of most rice weeds.

Several chemicals have been evaluated for their herbicidal effects when applied as a pre-emergence treatment to drilled rice and as a pre-planting treatment for water-planted rice. Results have not been satisfactory with pre-emergence treatment of drilled rice. The best time to apply herbicides for control of watergrass with pre-emergence chemical treatment is when watergrass is just beginning to emerge. In Arkansas and other southern areas, good watergrass control has been obtained by application of isopropyl N-(3-chloro)phenylcarbamate (CIPC) when the grass is in the one- to two-leaf stage. In experiments at Biggs, California, it was found necessary to irrigate at that time. Chemical treatment before irrigation injured the rice very severely. Eight pounds per acre of CIPC completely

eliminated rice. Chemical treatment after irrigation did not provide adequate control of the grass, though rice was not severely injured even at eight pounds.

In 1958, several herbicides were evaluated in preplanting experiments. In one series the herbicides were applied to the dry soil before flooding. In the second series, chemicals were applied while the soil was still wet from a preliminary irrigation. In both series the field was flooded immediately after treatment. Rice was planted in the water. Water depths were maintained at 2 to 4 inches. The chemicals were ethyl N, N-di-n-propylthiolcarbamate (EPTC), 2-chloro-N, N-diallylacetamide (CDAA), 2-chloroallyl diethyldithiocarbamate (CDEC), isopropyl N-(3-chlorophenyl) carbamate (CIPC), 2, 4-dichlorophenoxyethyl sulfate (sesone) (dry soil only) and 4, 6-dinitro ortho secondary butylphenol (DNBP) (wet soil only). The results in Table 2 show the degree of watergrass control and the yields of rice from the treated plots. All of the herbicides except DNBP provided some control of watergrass on the wet soil treatment. EPTC and CDAA produced high yields and good grass control. CIPC provided good grass control but was somewhat more severe on rice stand and yield. CDEC was less effective on the water grass and caused some injury to the rice, but yields were good.

Only one herbicide, EPTC, provided any degree of control of grass on the dry soil treatment. Severe injury to rice occurred at rates of 2 and 4 lbs/A of EPTC. At one pound per acre, control was good and rice yield was significantly greater than in the untreated check.

Because of practical difficulties in pre-irrigation, which was practiced in the wet soil treatment, the success of the dry soil application with EPTC is particularly interesting. To see if there was actually some selectivity or difference in tolerance of rice and watergrass to EPTC, some greenhouse experiments were conducted. It was felt that, under field conditions, rice and watergrass were not equally exposed to the herbicide.

Rice and watergrass were planted in identical conditions but in different containers. Measurements of height and fresh weight of rice and watergrass were made at six weeks of growth. Table 3 presents the results of the experiment, in which both flooded and unflooded culture were compared. It is evident that rice will tolerate more EPTC in the soil than will watergrass.

It is necessary to investigate several factors that will affect successful use of EPTC in rice: 1) rate of application, 2) method of application and incorporation, and 3) time of application in relation to flooding and planting.

Table 1. Yields of rice from plots treated with MCPA and 2,4-D at six dates in three years (100 lbs/acre)

Age of rice (days)	2,4-D			MCPA		
	1956	1957	1958	1956	1957	1958
48	28.9	45.7	46.9	57.2	67.7	50.2
54	----	59.9	45.5	----	60.9	48.3
61	54.1	66.6	47.7	57.6	65.3	45.9
69	----	61.6	45.2	----	68.1	46.6
75	46.1	54.6	44.7	53.1	64.2	49.9
82	----	55.8	43.0	----	60.6	46.2
Treatment average	43.0	57.4	45.4	56.0	64.5	47.8
Check	56.5	66.5	46.8	56.6	66.5	46.8
LSD	12.4	10.0	NS	12.4	10.0	NS

Table 2. Transect counts of watergrass (15-foot line transect) and yield (sacks per acre) of rice treated preplanting with several herbicides on dry soil and wet soil.

Herbicide	Rate (lb/A)	Wet soil: Watergrass counts	Wet soil: Rice yield	Dry soil: Watergrass counts	Dry soil: Rice yield
Check		50.5	30.7	56.0	26.2
EPTC	1	19.2	38.0	13.7	39.9
	2	8.1	37.3	9.7	24.8
	4	1.1	46.0	0.0	17.1
CDAA	2	14.6	47.0	48.7	32.5
	4	9.4	49.2	59.7	30.0
	8	4.0	48.3	45.0	31.5
CDEC	2	29.1	39.0	62.0	29.0
	4	16.3	42.4	65.3	28.2
	8	7.2	44.7	33.7	31.2
CIPC	2	22.3	36.6	53.7	24.6
	4	1.8	43.2	44.0	31.0
	8	2.1	27.5	36.3	25.5
Sesone	10	----	----	67.0	32.4
	20	----	----	73.3	37.2
	40	----	----	43.7	31.8
DNBP	2	47.7	29.3	----	----
	4	38.4	32.6	----	----
	8	31.7	38.4	----	----
LSD		7.7	12.9	23.1	10.0

Table 3. Fresh weight and height at 5 weeks of rice and watergrass plants grown in the No. 2 tin cans under two conditions of culture and several concentrations of EPTC in the soil. (Per cent of checks)

Rate (ppm)	Rice			
	Upland		Lowland	
	Height	Fresh wt.	Height	Fresh wt.
0	100	100	100	100
0.25	79	88.4	100	92
0.50	35	16.3	78	59
1.0	17	11.6	46	32
2.0	5.8	----	45	10
4.0	dead	----	14.5	1
	Watergrass			
0	100	100	100	100
0.25	21	39	30	26
0.50	13	13	21	12
1.0	3	----	13	3
2.0	dead	----	9	2
4.0	dead	----	----	----

BIOLOGY AND CONTROL OF INSECTS AND OTHER INVERTEBRATE PESTS AFFECTING RICE IN CALIFORNIA

W. H. Lange and A. A. Grigarick

I. Tadpole shrimp experiments.--On June 5, 1958, chemicals were applied to 1/10-acre rice blocks at Biggs for control of the tadpole shrimp, *Triops longicaudatus*. Forty shrimps were previously placed in three screen cages in three locations in each check. Live, dying, and dead shrimps were counted 24 and 48 hours after treatment. The results (Table 1) indicate 100% mortality in 48 hours from copper sulfate solution, DDT emulsifiable concentrate, malathion, or diazinon. Kills in 48 hours were satisfactory from copper sulfate crystals, DDT granules, #1189, and thimet seed treatment. Copper sulfate in solution gave the most rapid kill: all dead in 24 hours. This indicates that one possible reason for lack of control with copper sulfate crystals is that they do not go into solution immediately in all cases. This work also indicates that malathion, #1189, and diazinon are potential candidates for use in tadpole shrimp control. The high toxicity of thimet would probably preclude its use as a seed treatment in rice fields.

II. Leaf miner chemical control experiments.--Two series of hand-applied chemical control experiments were conducted during 1958 with two objects in mind: 1) to check on any possible resistance of the leaf miner to dieldrin; and 2) to test new chemicals as possible substitutes for dieldrin. Plots 15 x 25' were sprayed with chemicals and compared with untreated adjacent plots strategically placed to avoid possible contamination. Table 2 summarizes results of the Biggs and Bromley experiments.

One hundred rice plants were pulled from each plot 72 hours after treatment and examined under a microscope for live, dying, and dead larvae, eggs, and pupae. Of the 100 plants pulled, at least 25 showed mines.

Dieldrin in both experiments gave 100% mortality, indicating a lack of resistance at this time. Bayer 25198, Bayer 25141, and diazinon gave

good kills of larvae. Control was poor with demeton (Systox), phosdrin, 12880, 1189, dicapthon, and CP 10502. Fair control with thimet, guthion, and korlan indicated the possibility of effective control with higher rates.

These tests indicate that dieldrin at 4 ounces of actual material per acre is still satisfactory for control of the rice leaf miner, Hydrellia griseola.

III. Seed treatment tests for control of the rice leaf miner.--Greenhouse and field experiments were conducted with rice seed treated with the systemics thimet and di-syston to determine the value of a preplant preventive treatment.

Greenhouse experiments initiated April 3, 1958, indicated an increase in larval mortality with an increase in dose, when seed was soaked 24 hours in 0.25, 0.5, and 1.0% of thimet and di-syston and germinated in water. The larval mortality with thimet with increasing dose ranged from 91 to 100%, and with di-syston from 11 to 69%. The same trend was indicated when seed was treated with slurries and planted in soil. Di-syston and thimet at 32 and 80 ounces, respectively, of 50% and 44% material on activated carbon indicated no larval mining in the leaves, in comparison to 74 to 76% mined leaves, respectively, for the untreated and thiram alone.

In a field experiment at Biggs, seed soak and slurry treatments gave no indication of control (Table 3). There is an indication that kill in the greenhouse is due primarily to vapor action and not systemic transfer in the plants.

More seed treatment trials will have to be run, but so far it seems that seed treatment utilizing systemic action for leaf miner control does not seem practical with thimet and di-syston and several other organo phosphate systemic insecticides used in the ways tested.

Table 1. Results of tadpole shrimp experiment, Biggs, treated June 5, 1958.

Treatment (per acre)	% mortality at specified time intervals after treatment					
	24 hours			48 hours		
	Live	Dying	Dead	Live	Dying	Dead
1. Check	77.8	14.8	7.4	56.0	22.0	22.0
2. Copper sulfate crystals, 10 lbs.	0.0	30.0	70.0	7.9	0.0	92.1
3. Copper sulfate solution, 10 lbs.	0.0	0.0	100.0	----	----	----
4. DDT 50% granules, 4 lbs.	20.0	50.0	30.0	7.5	5.0	87.5
5. DDT, E.C., 2 lbs. actual	0.0	97.5	2.5	0.0	0.0	100.0
6. Malathion E. C. 2 lbs. actual	5.0	17.5	77.5	0.0	0.0	100.0
7. Dieldrin E. C. 0.5 lb. actual	72.7	18.2	9.1	6.1	51.5	42.4
8. #1189 E. C., 2 lbs. actual	10.0	22.5	67.5	7.5	0.0	92.5
9. Diazinon E. C., 2 lbs. actual	0.0	30.0	70.0	0.0	0.0	100.0
10. Thimet 1% seed treatment, 150 lbs. seed	0.0	45.0	55.0	0.0	2.5	97.5

Table 2. Summary of results obtained in rice leaf miner chemical control experiments, 1958.

	Treatment	No. plants examined	No. larvae			% dead & dying	Per cent control
			Live	Dying	Dead		
Exp. #1, Biggs Exp. Station, sprayed June 7--72 hr. check							
A-1	Check	28	33	0	5	13.2	----
B.	Dieldrin E.C., 4 oz. act./A	43	0	3	11	100.0	100.0
C.	Thimet E.C., 4 oz. act. per acre	25	9	6	28	79.1	75.9

(continued)

Table 2. Summary of results obtained in rice leaf miner chemical control experiments, 1958.

Treatment		No. plants examined	No. larvae Live	Dying	Dead	% dead & dying	% control
Exp. #1, Biggs Exp. Station, sprayed June 7--72 hr. check							
A-2	Check	45	16	0	5	23.8	----
D.	Systox E.C., 4 oz. act. per acre	60	30	0	7	18.9	0.0
E.	Guthion E.C., 4 oz. act. per acre	26	6	2	25	81.8	70.9
A-3	Check	37	30	0	7	18.9	----
F.	Phosdrin E.C., 4 oz. act. per acre	45	24	6	7	35.1	20.0
G.	Diazinon E.C., 4 oz. act. per acre	25	5	0	47	90.4	90.1
A-4	Check	25	35	0	1	2.8	----
H.	1189, 1 lb. act. as W.P.	49	13	1	9	43.5	15.3
I.	Bayer 25198, 4 oz.	35	0	0	14	100.0	100.0
J.	Bayer 25141, 4 oz. act. per acre	26	0	0	12	100.0	100.0
A-5	Check	39	12	0	6	33.3	----
Exp. #2, Bromley, Sutter Basin, sprayed June 10--72 hr. check							
A-1	Check	25	13	0	0	0.0)) 3.0	----
A-2	Check	27	19	0	1	5.0)	----
B.	12880 E.C., 4 oz. act. per acre	27	11	0	1	8.3	5.5
C.	18706 E.C., 4 oz. act. per acre	25	14	1	1	12.5	9.8
D.	1189 E.C., 4 oz. act. per acre	29	16	0	1	5.9	3.0
E.	Korlan E.C., 4 oz. act. per acre	26	3	0	10	76.9	76.2
F.	Dicapthon E.C., 4 oz. act. per acre	27	8	0	5	38.5	36.6

(continued)

Table 2. Summary of results obtained in rice leaf miner chemical control experiments, 1958.

Treatment	No. plants examined	No. larvae			% dead & dying	% control
		Live	Dying	Dead		
G. CP 10502 E.,C., 4 oz.	25	13	0	2	13.3	10.6
H. Dieldrin E.C., 4 oz. act. per acre	25	0	0	9	100.0	100.0

Table 3. Results of seed treatment tests for control of the rice leaf miner, Hydrellia griseola, at Biggs, May 16, 1958.1/

Treatment	Rate	Plant height (inches)	Incidence and extent of infestation		
			Av. % total leaves mined	Av. severity rating on 1 st. leaf above water 3/	Av. % 2nd leaves mined 4/
Test #1--Treatment by seed soak 2/					
1. Check	----	15.4	59.0	3.3	37.5
2. NaOCl (5.3%)	0.05%	15.5	60.2	2.5	23.3
3. Thimet 44% + Tr. 2	0.25%	15.3	60.2	2.7	26.7
4. Thimet 44% + Tr. 2	0.50%	15.9	62.8	2.7	40.0
5. Thimet 44% + Tr. 2	0.75%	15.0	57.0	2.3	23.3
6. Thimet 44% + Tr. 2	1.00%	15.0	60.2	2.3	33.0
Test #2--Treatment by seed soak and slurry 5/					
1. Check	----	16.9	58.0	4.0	55.0
2. Demeton (26.2%)	0.50%	18.4	70.0	3.5	65.0
3. #12880 Am. Cy. (48%)	0.50%	18.2	69.5	3.5	47.5
4. #18706 Am. Cy. (25%)	0.50%	16.9	52.5	4.0	45.0
5. Di-syston (50%) on C	32 oz/100 g.	19.3	68.5	3.5	72.5
6. Thimet (44%) on C	32 oz/100 g.	16.8	68.0	4.0	67.5

1/ Rice plots had a high natural infestation of the leaf miner, 20 plants from each plot were examined June 9

2/ Six replications of plots 6 x 6', seed soaked 24 hours, drained 48 hours.

3/ 100% of the first rice leaves were mined in both tests; the severity ratings were based on the estimated proportion of the leaf mined, as follows 1.0 = 1 to 25%; 2.0 = 26 to 50%, 3.0 = 51 to 75%, and 4.0 = 76 to 100%.

4/ The severity of mining for the second leaves with mines ranged from 1 to 25% in both tests.

5/ Two replications of 6 x 24' plots; seed soaked (1-4) 24 hours, drained 48 hours, treatments 5-6 were treated 5/14 by slurry using Wallpol 9303 4% + 2% water.

IMPROVED PROCEDURES IN ARTIFICIAL DRYING OF WESTERN RICE

Ted Wasserman

California produces about 11 million bags of rough rice annually. All is artificially dried, mostly in large commercial dryers using heated air. Breakage of rice may occur if the drying process is improperly done. Since rice breakage leads to losses of revenue for all segments of the industry, proper methods for drying are highly important.

My talk covers laboratory- and plant-scale studies of rice drying and tempering by the Western Regional Research Laboratory. I will also outline testing methods and equipment that enable the plant operator to find the best drying conditions for his particular plant and needs.

Work on rice drying at the Western Laboratory has progressed through 4 stages:

First, laboratory-scale studies to show how the various drying variables affect head yield and drying time;

Second, demonstrations that laboratory results can be profitably applied to commercial-scale operations;

Third, development of a testing system for the plant operator's use in obtaining the best results from his own equipment; and

Fourth, a demonstration that our published testing procedure is suitable for plant personnel.

Laboratory studies.--The object of the laboratory studies was to determine how drying time and milling yields are affected by such factors as drying air temperature, number of drying stages or passes, humidity, air velocity, and bed thickness. The dryer operator can control two of these--drying air temperature and number of passes through the dryer. When we varied these two factors, head yield and drying time were changed according to a definite pattern. A diagram was developed that shows the relationship between the 4 factors: air temperature, number of passes

through the dryer, drying time, and head yield. This diagram, which many of you have seen before, can serve as an operating guide in drying rice. It tells an operator what will happen if he changes his operating conditions. It also tells him what changes should be made, depending on whether greatest dryer capacity or highest head yield is needed at the time. Because it forms the basis for improvement in drying procedure, I will show the diagram again in a simplified form (Fig. 1).

The three heavy lines show total drying time at different air temperatures for 1-, 3-, and 5-pass drying. Conditions at any point on these curves will give a definite head yield. Dashed lines join points on the three curves that give the same head yield. This diagram points up the following facts:

1. If we increase the number of passes without changing the air temperature, drying is faster and head yields are higher.
2. If we increase air temperature without changing the number of passes, again drying is faster but head yields are lower.
3. Combinations of greater numbers of passes and higher air temperatures, if properly chosen, will give both faster drying and greater head yields.

The type of relationships shown in this diagram has been found with both Colusa 1600 and Caloro rice. It has been verified for two seasons with Caloro rice. Tests by southern experiment stations indicate that the same relationships hold for medium- and long-grain rice. I must emphasize that this diagram must be used as a guide only, because numerical values will vary from dryer to dryer. The pattern will not change.

In drying rice, only part of the drying is done in each pass through the dryer. After each pass the rice is stored to allow the moisture in the grain to equalize. The storage period between passes is called the tempering period. Up to now, adequate tempering has been decided by some

vague criterion such as smell or feel, or by some arbitrary time limit, about 12 to 48 hours.

Vapor pressure measurements show that short-grain rice is completely tempered in about 12 hours at 90° F. Tempering is about 90% complete in the first six hours. We made a study to find how short a tempering period would be adequate and practical. To determine this, rice was dried in 3 passes with 110° F. air with tempering periods of 0, 4, 8, 16, and 32 hours. Tempering was done at rice temperatures of 105° and 75° F. At 105° F., short-grain rice was adequately tempered in 4 hours. At 75° F., 6 hours are needed. The tempering time was judged to be adequate when a longer time did not give a change in head yield or drying rate. Different tempering times did not change storage characteristics.

Short tempering times are of great help in plants short of tempering bins. In <u>any</u> plant, short tempering periods can cut down the accumulation of partly dried rice at the start or end of the season. This simplifies handling of loads at the peak of the season. Also, keeping the plant clear of partly dried rice will make it easier to cope with a great influx of rice should there be rainy weather during harvest. In addition, by recirculating <u>seed</u> rice on a short-tempering-time schedule, cleaning equipment after each pass to avoid contamination becomes unnecessary.

Plant-scale studies.--As we all know, laboratory results are of unknown value until proved in actual plant operations. Therefore, we developed equipment and methods for making drying tests on a plant scale. We then demonstrated that higher milling yields and greater dryer capacity can be obtained by applying information from our laboratory studies.

Demonstrations were made in two modern drying plants, each using a different type of dryer. The cooperation we received in these plants was excellent. Improvements were so obvious that the plants adopted the new operating conditions immediately, and now use them routinely. Germination values were not affected in any of the tests.

The first test was made at the Sutter Basin Rice Growers Co-Operative plant. This plant uses dryers in which the rice is continually mixed during drying. Our first job was to make observations on drying as normally practiced in this plant. To do this we followed a lot that was dried by the usual procedure, collecting data and samples along the line to evaluate drying rate and changes of milling yields. We determined the milling yields of rice going into and coming out of the dryer on every pass, and found that the operators were doing a good job in maintaining milling quality. We felt, though, that it would be possible to increase their dryer capacity considerably without loss of milling quality. Operating changes that might lead to higher plant capacities and better milling yields were then decided on by use of the 4-variable diagram (Fig. 1). Drying runs were then made under the modified conditions. We found that increasing the feed rate 40%, from 1260 to 1760 bags per hour, and at the same time increasing air temperature from an average of 119° to 137° F. gave the following results:

Drying capacity was increased 58% in spite of the fact that one extra pass through the dryer was required. Head yield was increased 2-1/2% and total yield 1-1/2%. Drying costs were decreased 1-1/2 cents per bag.

The second series of plant-scale tests was made the following year, at the Farmers' Rice Growers Cooperative at Sacramento. This plant uses the Berico dryer, which is a non-mixing type. Here we followed the procedure used the previous year at Sutter Basin. Again we found that the operators were maintaining good milling yields in drying by their usual procedure. Again we increased the feed rate, from 1000 to 1900 bags per hour, and established two sets of improved conditions for different situations.

At the peak of the season or during wet weather, drying capacity is the factor of greatest importance. For this situation we raised the air temperature to 137° F. Drying capacity was increased 37%, and drying

costs were reduced 1 cent per bag. The number of passes increased from 3 to 4. Decreases of only 1.4% in head yield and 0.4% in total yield accompanied this increase in plant capacity.

At the start of the season or when rice is not piling up, milling yields are of greatest importance. For this situation we used an air temperature of 117° F. and the high feed rate of 1900 bags per hour. The number of drying passes increased from 3 to 6. Head yield was increased 2% and total yield 0.5%. Drying capacity increased 8%.

During the test at Farmers' Cooperative we also demonstrated that 4 hours were adequate for tempering short-grain rice on a commercial scale provided the rice is not cooled between passes. To show this, two lots of rice were dried under the same conditions except for variations in the tempering period. On one lot we used the conventional 12- to 24-hour tempering periods; on the other lot we used 4-hour periods. Drying time, milling yields, and germinations were about the same in the two tests. The lot tempered for 4 hours was dried and cooled for storage in an elapsed time of 18-1/2 hours between start of drying and final storage. Under the normal tempering procedure the rice would have been in process for 2 to 4 days.

Control of the dryer by watching rice temperatures was found to be of only limited value. Control by means of the amount of water removed in each pass was also of doubtful value because moisture measurements are usually made in the plant with electronic instruments on untempered rice. Measurements so made are inaccurate.

Commercial drying tests and visits to plants showed that <u>NO SINGLE RECOMMENDATION</u> will fit all plants and situations. Correct operation for a particular plant is determined by such factors as dryer type and size, capacity of conveying equipment, bed depth, quantity of air and its velocity through the rice, and tempering and storage space.

Unlike most processing operations, rice drying plants usually do not yet use quality control systems. This lack usually proves to be quite costly. The dryer operator is badly handicapped because he does not know the milling quality of the rice either as it enters the plant or after drying. Consequently, he has no way of knowing how to change his drying conditions to get better results. If he wants to make changes, he cannot determine what the effects will be.

To satisfy these needs, a simple method was developed to help the dryer operator find the best operating conditions for his plant. The method requires no extra help and only a small amount of additional equipment. Costs of such equipment would be around $1500 to $2000. Descriptions of required equipment and step-by-step instructions for its operation have been published.

The method is similar to that found effective in our plant-scale studies, with some changes to adapt it to plant personnel and equipment. The key to these tests is a practical method for determining the milling quality of the rice at any point in the drying process. This is done by taking a sample and slowly drying it with 75° F. air in a special sample dryer so that little or no damage is done to milling quality. The dried rice is then tested for milling yields. Comparisons of values for samples taken at various stages in the plant dryers show when any damage is done.

Briefly, the method consists of the following steps:

A drying run is made by the usual plant procedure. Samples are taken from rice entering the dryer in the first pass (green rice) and rice leaving the dryer in all passes. Each sample consists of about 15 or 20 subsamples taken periodically during the pass. Then each sample is thoroughly mixed, tempered, and tested for moisture content. A definite quantity is weighed into a sample tray and dried with 75° F. air to 13.5% moisture. Each dried sample is then mixed, placed in a can, and sent to

the Federal-State Grain Appraisal Laboratory for a milling test. By this means the milling quality of the green rice, as well as breakage that may occur during drying, are determined. Drying times for all passes are recorded to determine drying rate.

Other runs are then made at higher feed rates and higher air temperatures, using the same sampling and testing methods, until the best drying conditions are found. Air temperatures are never raised without increasing feed rates, and then only in small steps so as to avoid danger of serious damage to rice quality.

Commercial-scale tests indicate that feed rates and air temperatures can often be raised materially and give higher milling yields and faster drying.

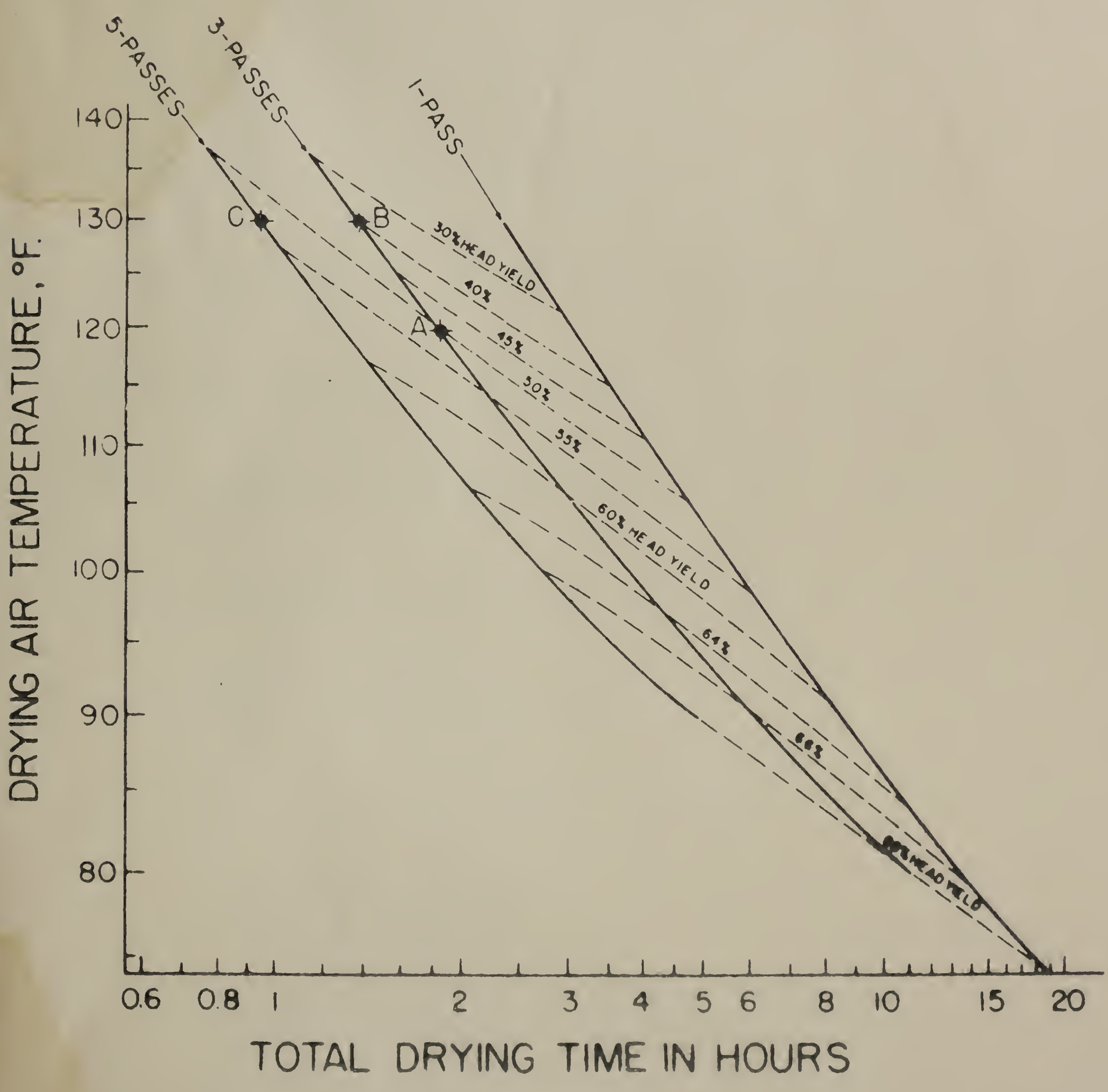
Last year we worked with a dryer in Louisiana. One objective was to see whether our test methods are practical for plant personnel. We found that they could easily perform the tests. It required only about two hours a day. The work was readily sandwiched in with their other duties.

What does this mean to the rice industry in dollars? At Sutter Basin, we found that if the new procedures had been used all season, income would have been increased by about $30,000 per year to the growers alone. Moreover, the increased drying capacity is a very real benefit, although it is hard to put a dollar value on this factor. With greater drying capacity, growers can harvest at higher moisture content. They will not have to delay harvest, since the dryer will be able to handle more rice. Thus, losses in milling yields from overdrying in the field can be reduced. The miller also gains from grain with higher milling yields. If we can raise the head yield for all of California by only 1%, the rice industry stands to gain at least $150,000 per year. This figure assumes the lowest differential paid for head yield in recent years. Usually the figure is higher.

If all commercial dryer operators use our procedure to find more effective operating conditions, the annual earnings of the California rice

industry might be increased by several million dollars. We shall be pleased to furnish dryers, extension people, and others with detailed information on how to apply the test procedures.

Fig. 1



STUDIES OF UNHEATED AIR DRYING OF RICE

S. Milton Henderson

Deep-bed unheated-air rice drying systems continue to perform properly when they are designed and managed as recommended in California Agr. Expt. Sta. Leaflet 103. Equipment is available for adding a small amount of supplemental heat to ensure satisfactory performance during prolonged wet periods. A procedure is now available for computing the required pressure for tunnel-type systems. Management procedures that should be emphasized to ensure satisfactory drying are:

1. Do not pile the grain deeper than system design (air capacity) permits. Overloading a dryer reduces the air rate per sack and may produce such slow drying that spoilage results before a safe moisture content is reached.
2. Do not attempt to dry excessively wet rice. Rice with moisture content above 25%, especially if many blanks are present, contains too much water to be removed safely before spoilage can result unless the recommended air rates are exceeded.
3. Keep foreign material at a minimum. It not only restricts localized air flow in the mass but frequently has a much higher moisture content than the grain. Also, cracked material respires faster than comparable whole material. Each of these (three) factors promotes early spoilage. If most of the foreign material is not removed by the combine, a scalper should be used at the dryer before storage. The remaining foreign material should be distributed uniformly throughout the grain mass.
4. In reversible air systems, do not reverse the air direction before the mass is two-thirds dry. Earlier reversal will leave the center mass of grain undried, and spoilage will probably result. Extra drying before reversing is far better than reversing too soon.

IRON DEFICIENCY OF RICE

W. E. Martin

Experimental applications of ferric sulfate to nonsaline alkali spots in rice fields have greatly increased yields.

Failure of rice in alkali spots--limited areas within otherwise productive fields--has been a problem for a number of years. In some instances, the spots are on soils that are clearly alkali and where other crops such as barley, sugar beets and safflower also fail. In different spots, nonirrigated barley and other crops grow reasonably well, but rice dies when planted in the same areas.

However, in the fall of 1953 almost all the rice died in a field on a ranch eight miles south of Grimes. Only a strip of excellent rice existed along the course of a narrow slough meandering through the field. Normal growth of previous crops of barley on the same land had been reported. Preliminary examination of the soil where the rice had died showed no appreciable salinity because the conductance was 1.23 millimhos per centimeter, much below the 4.0 value considered to be the lower limit of salinity. Neither was it an alkali soil because it had only 5% exchangeable sodium as compared to the 15% commonly used as threshold value.

<u>Soil samples tested.</u>--Samples of the good rice soil and of the bad rice soil were taken to Berkeley for nutritional studies in the greenhouse and for chemical analysis in the laboratory. The standard fertility assay for nitrogen, phosphorus and potassium was set up in the greenhouse in the spring of 1954 on both good and bad soils. Half of the pots in each treatment were planted to barley and half to rice.

Barley plants grew well in the surface foot of both types of soil, showing only a nitrogen deficiency in the good soil and nitrogen and phosphorus deficiency in the bad soil.

Rice plants grown under flooded conditions germinated well in both good and bad soils. In the good rice soil, plants showed only a slight response to added nitrogen. In the bad rice soil, plants rapidly became chlorotic and within five weeks nearly all died, regardless of fertilizer treatment. When not flooded, the rice plants remained alive on the bad soil.

Since no major nutrient was responsible for rice failure, foliage sprays with the several micronutrients were made. Repeated sprays with iron tartrate caused a greening of the plants grown on the bad soil.

Soil treatments with ferric sulfate, ferric tartrate, and Versenol, a commercial product containing 4% iron derived from an iron salt of HEEDTA (hydroxyethyl ethylene diaminetriacetic acid) kept plants green and healthy.

Later greenhouse studies showed that iron deficiency did not occur if the soil was acidified prior to planting. The studies also showed that surface broadcast treatments with granular ferric sulfate gave correction at lower rates of application than did finely ground ferric sulfate mixed with the soil.

Field tests.--Field treatments were begun in Colusa County and adjacent areas in Yolo County in the spring of 1955. Soil treatments were made with iron chelates, commercial agricultural ferric sulfate (21.0% iron) at 1,000 and 2,000 pounds per acre and technical ferrous sulfate (19.9% iron) at 1,000 pounds per acre. All materials were broadcast upon a rough, cloddy seedbed. The field was flooded and seeded immediately after treatment.

Rice germinated well throughout the entire area but began to turn yellow, and the leaves floated on the surface of the water after about a month. In the areas treated with ferric sulfate, ferrous sulfate, and Versenol iron chelate, rice remained green and continued to grow.

By mid-June many of the plants in the untreated area had died and open water remained, with some few plants surviving. These remaining plants recovered in July, tillered well, and made a fair crop. At maturity, cut quadrats showed that the yield had been increased from about 1,100 pounds of rice per acre to over 3,700 pounds with the application of 2,000 pounds ferric sulfate. Where 1,000 pounds of material was used, ferric sulfate gave a yield of 2,800 pounds, ferrous sulfate 2,500 pounds, and Versenol at 800 pounds per acre gave a yield of 3,000 pounds rice per acre. The results of this first demonstration showed clearly that the failure of rice to survive was related to an iron deficiency, and could be corrected by applications of iron sulfates--as well as by a suitable iron chelate.

In the spring of 1956 additional demonstrations were set up to test the effectiveness of agricultural ferric sulfate on problem soils. One such test was set up on a known alkali spot on a ranch south of Grimes. Duplicate quarter-acre plots were treated with 500, 1,000, and 2,000 pounds of material broadcast on the surface just prior to flooding. Gypsum at five tons per acre was applied to a small area in one of the untreated areas. Results from ferric sulfate were most striking. Nearly all of the rice in the control and gypsum-treated areas died. Yields in the control areas were estimated at 200 pounds per acre. Where treated with ferric sulfate, whether 500, 1,000, or 2,000 pounds, the rice grew well, and measured yields of 3,600-4,500 pounds of rice per acre were obtained with a commercial harvester. The following year safflower was planted in the experimental area and died from alkali damage, even in the areas where good rice had been grown with ferric sulfate treatments.

In 1957 a number of strip treatments were made in areas known to be affected with alkali, or on soils where rice had failed following successful crops of barley, sugar beets, or other field crops. In a test on a ranch

just south of the Yolo County line the effectiveness of 500 pounds of ferric sulfate broadcast just prior to planting showed clearly, as did the second-year effect of the ferric sulfate applied in 1956.

A replicated rate test was set up in 1958 on the same ranch and on the areas left untreated in the two previous years. Rates of 250, 500, and 1,000 pounds ferric sulfate were applied as long strips, each replicated three times across the affected area. Yields, as measured by a commercial harvester cutting out each strip, were increased from 1,625 pounds per acre on the control up to nearly 3,583 pounds per acre where 500 pounds ferric sulfate were used. On this soil 250 pounds per acre were clearly not enough and no advantage resulted from increasing the application to 1,000 pounds per acre.

Glenn County tests.--Field tests were initiated in Glenn County in 1957 on an alkali area 12 miles east of Willows. Treatments were laid out to compare ferric sulfate with ferrous sulfate at 500, 1,000, and 2,000 pounds per acre and with a treatment of 900 pounds of sulfuric acid per acre. All treatments were crossed with a strip of five tons of gypsum per acre to provide calcium equivalent to the exchangeable sodium in the top 6" of the soil. No effect of the gypsum and only slight result of the sulfuric acid were observed.

At each rate of application, commercial ferric sulfate gave better growth than equivalent iron from ferrous sulfate. No carryover effect of any treatment was observed on rice growth in the experimental area the following year.

Replicated rate tests to determine for each case the effectiveness of ferric sulfate were set out in 1958 on fields with a wide range of alkali conditions. Three plots were harvested. Two showed definite increases in yield of rice from the use of ferric sulfate, with no effect at the third site, where production was good.

There were definite responses to ferric sulfate on a bad alkali spot five miles south of Willows, but total yields were low.

On a less severe alkali spot, five miles north of Glenn and two miles west of the Sacramento River, striking differences in early growth were observed. By mid-July, rice in untreated areas had recovered, and, at harvest, yield increases due to ferric sulfate were only 500-800 pounds per acre.

Soil conditions.--The spots where rice fails because of iron deficiency usually represent 2-3 acres up to 50 acres. Examination of the soils where responses to ferric sulfate have been observed show a wide variation in alkali status.

The first group of soils would be classified as normal nonsaline-nonalkali soils with pH (relative alkalinity-acidity) values in the neutral range, a little above and a little below pH 7. Rice from these three locations grew normally, produced good crops, and showed no response to ferric sulfate. The salinity values ranged from 0.46 to 0.93 millimhos per centimeter conductance. From 2% to 6% exchangeable sodium was present.

The second group of soils upon which striking responses of rice to ferric sulfate were observed are ones where other field crops, such as barley, grow normally. These soils differ from normal soils only in that pH values increased with dilution to an alkalinity of nearly 9. Also, they show 3%-5% exchangeable sodium and a slightly higher salinity than the soils where rice grows normally. This group of soils may be classified as nonsaline-nonalkali soils with high pH. Carryover effects of ferric sulfate on succeeding crops of rice have been observed on such soils.

The third group of soils contain 11%--15% sodium, with low salinity. These show good responses to ferric sulfate but little carryover effect. Since per cent sodium values were at or below the 15% value, these soils are classified as nonsaline-near-alkali soils of high pH.

The fourth group of soils contain higher amounts of exchangeable sodium--30% to 40%--and about the same salinity as the first three groups. They are soils where crops such as barley and safflower fail but where rice may be encouraged to grow if iron is supplied to overcome iron deficiency. These soils would be clearly classified as nonsaline-alkali soils of high pH.

The fifth group, soil both saline and alkali, is represented by a single test. The soil had 66% exchangeable sodium, along with a conductance value of 4.8 millimhos--just over the saline threshold. Iron sulfate clearly increased yields, but production was low regardless of iron treatment. Whether the poor performance was due to high sodium, to high salinity, or to both is not known.

Soils where rice fails are calcareous and characterized by a high pH along with a relatively low salinity. Rice plants die of iron deficiency as seedlings because of low iron-supplying power of the soil, which seems to be associated with high pH under flooded conditions.

Ferric sulfate appears an effective means of raising rice production to economic levels on high-pH nonsaline soils that occur as localized spots in many fields in Glenn and Colusa counties. Where high salinity is encountered, ferric sulfate treatments may not be expected to be effective until the soluble salt content of the soil is reduced by leaching.

IMPROVING RICE THROUGH BREEDING

Milton D. Miller

In presenting this information to your group, I do so as a "pinch-hitter." Rod Thysell, the USDA rice geneticist who normally would be giving this paper, is out-of-state, completing work on a Ph. D. The results reported represent a cooperative program of the USDA and the Department

of Agronomy of the University of California to provide California rice growers and rice marketers and world-wide consumers with better varieties.

The objectives of the rice breeding program at Biggs.--

1. Improve quality in existing varieties.
2. Improve straw strength in Colusa (CI 1600).
3. Incorporate "smooth hull" in all commercial varieties.
4. Develop an adapted "long-grain" variety for California.
5. Develop California varieties adapted to cold irrigation water.
6. Improve glutinous varieties adapted to California.
7. Improve Hoja Blanca disease resistance in certain varieties.
8. Maintain world collection of rice germ plasm.

<u>Progress</u>.--During the past several years, an extensive rice breeding and testing program has been conducted at the Rice Station, Biggs, and off-station in Glenn and Kern counties:

1. Screening of strains for cold water tolerance has progressed well in field studies on the Wylie, the Baker Brothers, and the Wilfred Carrier ranches along the Glenn-Colusa Canal in Glenn County.

2. Screening of long- and medium-grain strains and varieties has progressed well in tests in Kern County near Buttonwillow (cooperative with Kern County Farm Advisor Roy M. Barnes) and at Biggs. Three promising lines have been thus located.

3. Early Cal-Rose Selection.--This selection, made by Dwight C. Finfrock, of the Department of Agronomy, seems especially promising. It appears to be about 4 to 7 days earlier in maturity than Colusa, and at least 14 days earlier than its progenitor, medium-grain Calrose.

4. Below is information resulting from 1958 comparative yield tests at the Rice Station, Biggs, of the current commercial varieties and promising new experimental lines:

Variety	Yield Paddy Rice lbs/A
Calora	5480
Colusa	5630
Calrose	5700
Early Calrose Selection	6000
Best Long-grain variety*	5900

GREEN MANURING AND CROP RESIDUE MANAGEMENT IN RICE PRODUCTION

Dwight C. Finfrock

By using legume green manure crops, rice farmers can reduce cash costs, prepare land earlier, and improve the tilth of the soil. Moreover, crop residues can be put to profitable use.

Legume crops have proved to be best for green manures in rice fields because they grow well in winter, are easy to establish, and capture free nitrogen for future crop use.

Leguminous green manures are grown and turned under on about one fifth of California's rice land, and the practice, which has substantially increased yields, is expanding rapidly.

A series of field experiments were conducted to determine the nature of the effects of green manures and rice crop residue management on lowland rice production. Winter leguminous green manure was determined to be an inexpensive, efficient source of nitrogen that fits in well with continuous rice culture in the Mediterranean type of climate in California. The marked response of rice to leguminous green manure was duplicated,

* Variety is hardy and has stiff straw. More improvement and testing will be necessary before the Early Calrose Selection and the "best" long-grain variety can be released for commercial production.

for the most part, by inorganic nitrogen applications when properly placed in the reducing zone of the rice soil.

Leguminous green manure served to add nitrogen to the highly carbonaceous rice crop residues. This permits decomposition to proceed without tying-up nitrogen needed by the subsequent crop, and provides a satisfactory alternative to the deleterious practice of burning the residues.

Planting vetch in the standing rice should be done on the day most of the water has been drained from the field to several days later. In very dry years, planting a day or two before draining shows some advantages.

Depth of incorporation of green manures is important; efficiency of utilization improves with depth up to 6 inches. Table 1 shows the results of this study over a period of three years.

Table 1. Effect of depth of green manure incorporation on rice yield.

Depth	Yield lb. /A (14% moist.)		
	1956	1957	1958
Check	1330	3450	4190
Vetch 1 in.	2170	3980	----
Vetch 2 in.	3160	4770	5370
Vetch 4 in.	3580	5180	5650
Vetch 6 in.	3580	5590	5970
Amm. Sul. 2 in.	3370	4340	6120
LSD 5%	520	860	480

Time of incorporation of green manure is important in wet springs that delay field preparations. Delays in seed-bed preparations allow nitrification of nitrogenous compounds in the green manure, and nitrogen is lost following flooding, through denitrification.

Table 2 shows the results of two years' work. One spring was wet (1957) and the other dry (1958).

Table 2. Effect of time of incorporation of vetch green manure on yield of rice.

		Yield lb./A	
Date of incorporation		1957	1958
Check		2240	3210
Vetch	4/15/57; 5/1/28	3270	4910
Vetch	4/25/57; 5/8/58	4340	4400
Vetch	5/6/57; 5/15/58	4800	4810
Vetch	5/16/57; 5/22/58	5210	4720
Amm. Sul.	5/16/57; 5/22/58	4140	4740
LSD 5%		580	510
Flood Date		5/16	5/22

Rice straw left from harvest is hard to handle. It is hard to spread wet straw uniformly, and difficult to turn large amounts under during seed-bed preparation. Straw is slow to decompose and tends to tie up available nitrogen, reducing yields or requiring additional fertilizer. For these reasons, many farmers have burned the straw left after harvest. However, studies at the Rice Experiment Station suggest that soil productivity may be seriously depleted by continued straw burning.

The turning under of vetch or other green manure crops eliminates some of the problems of rice residue. When vetch is turned under with rice stubble there is less chance of nitrogen tie-up, because of the high-nitrogen content of the vetch. Tests have shown that the nitrogen content of rice stubble actually increases when a vetch crop is grown in it, particularly during a mild winter.

If the vetch crop is burned with the rice straw, almost no benefit is realized from the green manure crop. The nitrogen value of the vetch is

in the tops, which must be turned under to be an effective source of nitrogen.

ATTENDANCE

Rice Symposium

3/27/59

Glen R. Harris, Director and Treasurer--California Cooperative Rice Research Foundation

H. W. Barmann, Director--California Cooperative Rice Research Foundation

Regnor Paulsen, Director--California Cooperative Rice Research Foundation

W. J. Duffy, Jr. (Farmer) Chairman--California Cooperative Rice Research Foundation

James T. Munson--Rice Growers Association of California

Robert R. Mickus--Rice Growers Association of California, Sacramento

Kenneth L. Viste--University of California, Davis (ARS)

Douglas P. Ormrod--University of California, Davis (Agronomy)

Maurice L. Peterson--University of California, Davis (Agronomy)

Duane S. Mikkelsen--University of California, Davis (Agronomy)

Milton D. Miller--University of California, Davis (Experiment Station)

Franklin C. Raney--University of California, Davis (Irrigation)

W. Harry Lange--University of California, Davis (Entomology)

Dwight C. Finfrock, Superintendent--Rice Experiment Station, Biggs, California

S. Milton Henderson--University of California, Davis

W. E. Martin--University of California, Berkeley

W. B. Van Arsdel, Acting Director--Western Regional Research Laboratory, Albany

C. H. H. Neufeld, Assistant to Director--Western Regional Research Laboratory, Albany

George O. Kohler, Chief, Field Crops Laboratory--Western Regional Research Laboratory, Albany

James W. Pence--Field Crops Laboratory, Western Regional Research Laboratory, Albany

E. B. Kester--Field Crops Laboratory, Western Regional Research Laboratory, Albany

R. E. Ferrel--Field Crops Laboratory, Western Regional Research Laboratory, Albany

Ted Wasserman--Engineering & Development Laboratory, Western Regional Research Laboratory, Albany